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Implications of Game Theory for International Agricultural Trade

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Panu K.S. Kallio*

Research Discussion Paper No. 1
January 1996

Objective Analysis
for Informed
Decision Making

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The purpose of research discussion papers is to make research findings available to researchers and the public before they are available in professional journals. Consequently, they are not peer reviewed.

Implications of Game Theory for International Agricultural Trade

Market power in international agricultural markets is found in public agencies who are also redistributing economic benefits towards producers as a goal of domestic agricultural policy. Methods to address imperfect competition have mostly used conjectural variations, but some recent approaches apply explicit game theoretic methods. This paper extends one of the few game theoretic approaches to the analysis of GATT negotiations to find the rationality in an outcome in which export subsidies were not eliminated, but subjected to constraints. A stylized model of wheat trade illustrates the common approach to these issues, and how game theoretic methods may be applied.

Keywords: International agricultural trade, game theory, export subsidies, GATT

This session celebrates the Nobel prize recognizing contributions of game theory to economic analysis. It is especially appropriate that international trade be included, since both theory and practice in this area have been revolutionized as a consequence of issues game theory addresses. The "New International Trade Theory" evolved to deal with product differentiation, economies of scale, and imperfect competition (Helpman and Krugman). Ethier observed that this revolution was driven by the failure of existing models -- the Heckscher-Ohlin-Samuelson- framework -- to account for key observed trade practices, including the existence of and importance given by government policy to export subsidies. Understanding international market behavior and policy impacts in this instance requires methods which account for strategic interactions of market agents.

Agricultural trade research has for a long time recognized the importance of imperfect competition. McCalla in 1966 first argued that wheat trade be explained as a duopoly involving the U.S. and Canada. Carter and Schmitz and Alouze, Watson and Sturgess recognized that Japan, the U.S.S.R., and Australia also may exercise market power in wheat trade. The IATRC published a book on imperfect markets in agricultural trade in 1981 highlighting the importance of this issue (McCalla and Josling). A second conference examining the linkage between imperfect competition and political economy of trade policy was published in 1990 (Carter, McCalla and Sharples). Most approaches have utilized the conjectural variations method (e.g. Paarlberg and Abbott, 1986, 1987; Kolstad and Burris), an approach not included by strict game theorists among their tools (McMillan, Tirole). Some recent approaches have followed explicit game theoretic methods, however (Karp and McCalla; Hillberg; Johnson, Mahe and Roe; Kennedy, von Witzke and Roe).

Incorporation of complex theoretical approaches addressing imperfect competition, and especially based on game theory, into routine trade policy analysis is uncommon. For example, while issues of imperfect competition and strategic policy interaction lay at the heart of the recently concluded GATT agreement, most models used to assess trade liberalization impacts assumed competitive world markets, albeit with exogenously set policy instruments through which games may be played (Roningen, Sullivan and Dixit; OECD). Evaluations of the U.S. agricultural export enhancement program (EEP) have also generally used competitive models and exogenous policy instruments, and do not explicitly examine the game theoretic aspects of market outcomes (e.g. Haley and Skully). Johnson, Mahe and Roe demonstrated that explicit game theoretic analysis of GATT can yield insight into the negotiation process and its outcome, however.

This paper extends that analysis in search of the rationality behind the agreement on agriculture

in GATT, in which export subsidies were not eliminated, as many had hoped would be the case, but were subjected to financial and quantitative constraints (IATRC). As background and to provide insight into the rationale behind policy outcomes, lessons from the New Trade Theory and from the agricultural trade literature relevant to this question will be reviewed. A simple, generic model of agricultural trade addressing income redistributional goals of agricultural policy is presented to show the essential framework which lays behind much of this literature. Simulations using a stylized representation of the world wheat market illustrate, from a game theoretic perspective, why for the U.S. and European Union (EU), the GATT agriculture outcome may be a second best solution preferable to the status quo.

Game Theory and “New International Trade Theory”

Imperfect competition is one of the key ingredients in the “New International Trade Theory.” Contributions to this literature have been recently reviewed by Krugman, Krishna and Thursby and others. Empirical contributions in this area, including those for agricultural commodities, have also been reviewed by Sheldon. Those empirical contributions generally are used more to illustrate theoretical points than to provide guidance on policy setting, or to offer realistic simulations of markets. They are synthetic simulations (econometric estimation is seldom involved) and strategic interactions are typically captured using conjectural variations methods.

Krugman defends the use of conjectural variations as a simple means of capturing strategic interactions. It has yielded several useful insights into trade policy. This approach is also useful in empirical estimations where one goal of the exercise is to uncover the nature of strategic interactions, given a minimum of information on institutional structure in the market. Extreme outcomes

correspond to known structures. For example, Thursby and Thursby used this approach to identify that U.S.-Canadian interactions in wheat exports to Japan may be characterized as a Bertrand game.

Game theorists are critical of conjectural variations methods, likening them to a static snapshot of an inherently dynamic process. There is no reason a priori for conjectures to remain constant over time, except under the simplest of game structures (Helpman and Krugman), and a common empirical result is an intermediate case which corresponds to none of the special cases the conjectural variations method seeks to reveal, nor are they found constant over time (Paarlberg and Abbott).

Games in markets are played on a transaction by transaction basis, whereas we observe aggregate outcomes over longer periods of time. Game theorists are also accustomed to models yielding multiple equilibria. Hence, game theory is difficult to implement at the level desired by empirically minded agricultural economists.

McMillan shows that many of the results in "New Trade Theory" can be derived in explicit game theoretic frameworks. In those cases, as is typical of the work in game theory, market institutional arrangements must be established first, and results may be derived under that special case. In spite of this need for institutional detail, a number of findings from this literature may be noted which are relevant in interpreting the recent GATT outcome.

Trade interventions may be rational welfare enhancing policy. Subsidies, rather than taxes and tariffs, may be optimal under certain market structures. A classic example is the debate between Brander and Spencer and Eaton and Grossman, who show that simply changing a market structure assumption from Cournot to Bertrand can shift the optimal intervention from a subsidy to a tax. The most important lesson from this literature is that results, and so the rationale behind policies, is very

sensitive to the institutional structures invoked. A central thesis in this paper is that GATT establishes (changes) those market institutions, and so during negotiations players must be cognizant of consequences under alternative institutional arrangements which the agreement might put in place.

Imperfect Competition in Agricultural Trade

International agricultural markets often exhibit conditions under which game theoretic analysis is appropriate. A few large countries or regional blocs engage in trade of commodities - they are not "small countries" as required in traditional trade theory. Furthermore, institutions exist through which that market power in trade may be exercised -- the EEP program in the U.S. and the export restitutions of the EU, for example. That market power is vested more often in public agencies than in private firms (Patterson and Abbott, Caves and Pugel), and it is through policy interventions that the strategies are set. In fact, much of international agricultural trade involves parastatal agencies whose goals include redistribution of benefits toward producers (or consumers in some importing developing countries), possibly in response to successful rent seeking by special interest groups.

Making sense of observed agricultural policy, and of the existence of export subsidies, requires recognition of the producer bias in policy setting. Trade interventions are rational (if second best) since these public agencies have market power in trade. The rationality of export subsidies has been shown when export taxes are prohibited (as in the U.S. constitution), and targeting of subsidies permits a country to behave as a price discriminating oligopolist (Abbott, Paarlberg and Sharples). Policy makers, as well as the policy debate, make clear the importance of strategic interactions among players - both the U.S. and EU claim to be matching the other's export subsidies, suggesting that mutual reform might be advantageous. Kennedy, von Witzke and Roe demonstrate that for

wheat subsidies, this interaction can be viewed as a classic prisoners' dilemma game.

A variety of models and methods, cited earlier, have been proposed to address the consequences of imperfect competition between state agencies in trade. Many specify conjectural variations models, while a few are explicitly game theoretic. The common underlying structure among both types of models can be represented in the relatively simple framework presented below.

A Model of Redistribution in Imperfect Agricultural Markets

A stylized model of world wheat trade is utilized to illustrate under differing institutional arrangements (game structures) the levels of export subsidies (or taxes -- the strategies), net exports and the political payoffs for four regions (or players): the U.S., EU, CAIRNS and Importers. This model highlights the importance of redistributive goals of agricultural policy, captured by using a payoff function (government objective) which is a weighted sum of producer surplus, consumer surplus and government budgetary expense, and the potential strategic interactions among players, since their strategies (export subsidies) give rise to differing payoffs depending upon opponents' strategies. This simplified structure captures the essential elements of many of the contributions to this literature (e.g. Paarlberg and Abbott; Johnson, Mahe and Roe; Kennedy, von Witzke and Roe).

A supply-utilization accounting identity, or trade balance in an open economy, captures the effects of producer and consumer behavioral adjustments to policy, and hence prices, on trade:

$$E_k = Q_k(Ps_k) - D_k(Pd_k) \quad (1)$$

where E_k is exports from region k (imports if negative); Q_k is supply (production) in region k , which depends on Ps_k , producer support prices in region k , following a supply function; and D_k is demand (consumption) in region k , which depend on Pd_k , the domestic market price in region k , according

to a demand function. World market equilibrium requires:

$$\sum_k E_k = 0 \quad (2)$$

Price linkages relate border (world) prices to domestic market prices using policy instrument settings (exports subsidies and producer support via price interventions):

$$P_{d_k} = P_w + S_{w_k} \quad (3)$$

where P_w is the world price, S_{w_k} is the export subsidy (import tariff) offered by region k , and

$$P_{s_k} = P_{d_k} + S_{q_k} \quad (4)$$

where S_{q_k} is a coupled producer subsidy in region k , offered via a price intervention.

Political payoff functions (each player's objective in the game) are given by:

$$Z_{p_k} = W_{q_k} Z_{q_k}(P_{s_k}) + W_{d_k} Z_{d_k}(P_{d_k}) - W_{g_k} (S_{q_k} Q_k + S_{w_k} E_k + S_{dc_k}) \quad (5)$$

where Z_{p_k} is the political payoff in region k , Z_{q_k} is producer surplus for region k , Z_{d_k} is consumer surplus for region k , and S_{dc_k} is decoupled producer support in region k . Welfare weights are W_{q_k} for producers (U.S. 1.15, EU 1.30, Cairns 1.10, Importers 1.0), W_{d_k} for consumers (U.S. 0.85, EU 0.90, Cairns 1.0, Importers 1.0), and $W_{g_k} = 1$ (the numeraire) for government budget expense.

Initial equilibrium quantities, prices and supply and demand elasticities are taken from the ERS trade liberalization database (Sullivan, Wainio and Roningen) in our empirical implementation. A base year of 1986, when the Uruguay round commenced, is simulated using this data, and subsequent simulations are static. Linear supply and demand curves are assumed. For simplicity, only export subsidies are examined here, so S_{dc_k} and S_{q_k} are set at 0.

Alternative institutional arrangements may be represented by solving this model assuming governments set export subsidies in order to maximize political payoff in a manner corresponding to the agreement in place. Cartels of all exporters, and of the U.S. and EU, are examined by

specifying cartel objectives which are sums of member payoffs. Nash equilibria are found assuming the U.S. and EU independently maximize their own welfare with the subsidy level of its opponent taken as given. The new GATT agreement is represented by imposing subsidy expenditure limits in each player's maximization problem. (Nash equilibria are solved for the intersection of these best response functions by iteratively solving each region's problem given the opponents' strategies, or subsidy, using GAMS.) A free trade equilibrium, and the outcomes when either the U.S. or EU unilaterally reform by eliminating its export subsidies, are also considered, as well as cases when all welfare weights equal one (income redistribution is not a policy goal).

The weights are set so that the Nash equilibrium (without expenditure limits) corresponds roughly to the status quo (pre GATT). It is assumed the CAIRNS group is a non-subsidizing exporter in the base case, and exercises market power only in the exporter cartel simulation (to examine their interests in the GATT outcome). Importers are a "competitive fringe", never imposing a trade wedge here (or intervening as if a set of small countries with domestic objectives only).

The GATT Agreement from a Game Theory Perspective

The GATT agreement on agriculture can be characterized as containing two key elements. One is that producer support be encouraged through decoupled instruments which do not distort trade. In the context of this model, that means using S_{dc} rather than S_w or S_q to accomplish the fundamental goals of agricultural policy - redistribution toward producers. This is in trade theory parlance a move from second best to first best instruments. Export subsidies were not eliminated by GATT, however. Rather, no new subsidies may be introduced, and U.S. and EU agricultural subsidies are subjected to both financial and quantitative constraints (IATRC).

The initial U.S. proposal to GATT called for elimination of all agricultural subsidies, and especially explicit export subsidies, so many took the outcome of this round as disappointing. From a game theory perspective, GATT could have taken the players out of their prisoner's dilemma, and permitted a cooperative solution, or free trade, to prevail. But the major players - the U.S. and EU - have market power in trade, so continuation of a trade intervention may indeed be rational, and with their redistribution goals subsidies may remain a second best policy instrument. The situation prior to the GATT agreement reflected this situation - the existence of a trade intervention reflected market power in trade, and subsidies rather than export taxes reflected the producer bias of policy. The pressures which drove the negotiations included the increasing importance of reduced government expense (or in the case of the model, declining W_q relative to W_g), and the desire to move closer to a cooperative solution.

Table 1 reports outcomes of simulations of the alternative institutional arrangements, and hence potential GATT outcomes, for each of the cases described above. The presumption here is that GATT sets the rules for trade, and hence the institutional arrangement (or what game will be played), and under each structure, players will set their strategies in their self interest. The actual outcome corresponds to the "Constrained Nash equilibrium" where subsidy expenditures are limited to 64% of pre GATT levels found in the "Nash equilibrium". Export subsidies are the strategies and Z_{pk} are the payoff functions for each player. Cartels would form (the game would become cooperative) if in the self-interest of members, and if real world institutions would permit the cartel to hold together. Joint setting of subsidies by the EU and U.S., and explicit side payments, are probably GATT illegal and at least politically incorrect. These include alternatives rejected in the negotiation process.

These results, while only a stylized representation of this market, reflect the concerns and issues

raised above. The market outcome is a prisoners' dilemma in that unilateral reform is always the worst case for the country which reforms, and the best outcome for the country which retains its subsidies. Free trade is only the optimal outcome for the world as a whole, and so would not be a cooperative solution unless Importers' political payoff also counts. The U.S.-EU cartel is optimal for the two exporters taken together, but the U.S. would prefer the constrained Nash equilibrium unless a side payment were offered.

It is useful to note that subsidies are larger under the Nash equilibrium outcome than under the U.S.-EU cartel - implying that lack of cooperation has led to subsidies which are indeed greater than desirable (found under cooperation). Hence, by constraining subsidies to lower (non-zero) levels, the outcome is preferred to the status quo by both players, and a different distribution of benefits, not necessarily requiring side payments, is accomplished. Admittedly, the problem in coming up with this solution is in properly setting the subsidy limits, and GATT is a rather blunt instrument for that job. Also, redistribution is more important than strategic interaction in setting subsidy levels, since all subsidies and payoffs for non-cooperative games are in a similar range, and are much different from the free trade outcomes. When simulations are run with interest group weights equal to one, so the political economy aspect of the model is eliminated, optimal interventions are an export tax for the U.S. , an import subsidy for the EU under the Nash equilibrium, and a uniform export tax for the cartel. It should also be noted that the actual GATT limits imposed on subsidies reflect the diminishing importance put on producer welfare over time, and likely in the future.

The minor role of the CAIRNS group in determining the GATT final outcome is also consistent with these results. As a group of non-subsidizing exporters, with lower weights on producer welfare, an exporter cartel including CAIRNS would have had that region imposing export taxes rather than

subsidies. That is, as the region with the lowest weight on producer surplus, CAIRNS would have backed off the export market, and the higher prices would have benefitted all exporters at the expense of importers. Realistically, insuring that CAIRNS not introduce their own subsidies was probably as good an outcome as the U.S. and EU could have hoped for, and export taxes would have been quite unpopular in the CAIRNS countries and elsewhere.

Conclusions

Export subsidies exist in agricultural markets largely to complement domestic policy objectives fostering producer support. Trade interventions are used, however, due in part to market power in trade, and since that power resides in a few public agencies, strategic interactions in policy setting arise. The policy problem of these large exporters has been characterized as a prisoners' dilemma game, and GATT may be viewed as an institution through which the rules of the game in trade may be altered to move the market outcome closer to a cooperative solution. Free trade -- elimination of export subsidies -- is that solution only if cooperation is between all trading countries.

If GATT resulted in an EU-U.S. cooperative solution, it should not be entirely surprising that export subsidies persist. The stylized simulations presented here show that the actual GATT outcome, under which export subsidies of the U.S. and EU were constrained but not eliminated, may dominate the Nash outcome (or status quo) when constraints are not applied. Under the Nash scenario strategic interaction leads to subsidies which are just too large, but a cartel solution could require impractical side payments and is politically infeasible. The practical dilemma for policy makers now is in setting those constraints in a world where the impetus for redistribution toward producers is declining.

Now that the GATT agreement is completed, the problem of implementing its provisions remains for governments. Subsidy constraints were not set on a commodity by commodity basis, so an allocation problem for constraint expenses arises. Moreover, actual subsidies are targeted and so may vary by importer, complicating allocation issues. There are pressures for reform of EEP and EU target price mechanisms, as well, so that institutional arrangements will continue to evolve. For example, U.S. exporting firms want pre-announced subsidy levels, which would turn the U.S. into a Stackelberg leader in world markets.

Game theory is useful in understanding the nature of market outcomes when such policies matter. Agricultural policy games are now played on a transaction by transaction basis in an uncertain market environment, and where payoff functions are also changing over time. Dynamic games of imperfect or incomplete information may well be helpful in analyzing post-GATT policy choices.

Table 1. Export Subsidies and Political Payoffs from International Wheat Trade Under Alternative Institutional Arrangements

Market Institutional Arrangement	U.S.			EU			Cairns		Importers	
	Subsidies \$/ton	Exports \$millions	Payoff* million tons \$millions	Subsidies \$/ton	Exports \$millions	Payoff* million tons \$millions	Payoff* \$millions	Payoff* \$millions	Payoff* \$billions	Payoff* \$billions
Payoff Weights Favoring Producers										
Free Trade	0.00	0	24.2	569	0.00	0	- 3.2	1911	418	0
Exporter Cartel (U.S., EU and Cairns)	25.32	766	30.3	591	97.93	2454	25.1	3523	63	511
U.S.-EU Cartel	34.41	1125	32.7	583	108.29	3009	27.8	3527	35	662
Nash Equilibrium	40.50	1393	34.4	572	116.33	3493	30.0	3524	- 2	744
Constrained Nash Equilibrium	28.59	891	31.2	596	94.11	2236	23.8	3484	87	552
U.S. Unilateral Reform	0.00	0	22.2	330	116.77	3605	30.9	3598	105	515
EU Unilateral Reform		40.68	1484	36.5	812	0.00	0	- 3.9	1849	303
Payoff Weights = 1, Consumer plus Producer Surplus										
Free Trade	0.00	0	24.2	0	0.00	0	- 3.2	0	0	0
U.S.-EU Cartel	-3.78	- 88	23.1	8	- 3.78	16	- 4.2	- 4	19	- 27
Nash Equilibrium	-4.32	- 99	22.9	2	0.56	- 2	- 3.0	- 1	10	- 14

*Payoff is a weighted sum of producer surplus plus consumer surplus less subsidy expense (relative to unweighted consumer plus producer surplus under free trade). Weights are from Kennedy, von Witzke and Roe for the first set of simulations, and give subsidies close to 1986 levels in the Nash Equilibrium solution. A second set of simulations sets weights equal to one, corresponding to a conventional welfare measure which does not reflect income redistribution objectives of agricultural policy.

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